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WESTERN PINE SHOOT BORER MONITORING AND POPULATION REDUCTION GUIDELINES

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Introduction

The management of western pine shoot borer, *Eucosma sonomana*, on seed orchards, evaluation plantations, and in other young plantations is becoming more of a concern as foresters increase their ability to recognize infested terminal and lateral branch tips on young ponderosa pine and lodgepole pines, and as they become more aware of the extent of shoot borer damage to seed orchard and plantation trees. Ecosystem restoration activities in the Blue Mountains that emphasizes the regeneration of sites back to ponderosa pine, also elevates concerns that western pine shoot borer will become a significant pest problem as pine stands grow into susceptible size classes. This trend towards more intensive forest management heightens concern that the shoot borer may be a limiting factor in wood production in the future (Ross 1989; Stevens and Jennings 1977).

Currently, management of shoot borers is limited to maintaining healthy stands and vigorous growth, and using mating disruption with synthetic pheromones to reduce population numbers and subsequent shoot borer damage. Monitoring of populations with synthetic pheromone-baited sticky traps to determine population levels and establish treatment thresholds is also gaining in interest; yet, information and guidelines addressing monitoring, as well as the potential for other means of managing shoot borer populations such as by "trap-out" or combinations of trap-out and mating disruption, are not available in any one place. This type of information is either not in the published literature, or is only partially addressed. In some cases, investigations have yet to be undertaken to determine the potential for alternative means of managing shoot borer populations and preventing tree injury.

This document was written to provide information, guidelines, and advice on shoot borer monitoring and reduction of populations on pine seed orchards and plantations. Note that some of what is presented is not based on scientific studies. The information, guidelines, and advice presented are based on the published literature, and on professional experience, observations, and knowledge of western pine shoot borer, and

the use of behavioral chemicals to manipulate its populations. It is anticipated that this document will be revised as more information becomes available. Until then, we hope we have provided enough information to enable seed orchard managers and tree-improvement foresters to effectively use the monitoring and mating disruption tools currently available.

Biology

Western pine shoot borer is present in most yellow pines of the Western U.S. Adult moths emerge early in spring and oviposition starts about the time pine buds swell and continues as new shoots elongate. Larvae exit the shoot in July, fall to the ground and immediately pupate under ground litter. Pupae diapause until spring.

Larvae mine in elongating shoots, stunting shoot growth, and sometimes killing the shoot. The insects prefer terminal shoots over the much more abundant lateral shoots. Within a plantation, pine shoot borer selects for those terminal shoots that are potentially more robust and fast growing. Females apparently select shoots by ovipositing on or near the largest terminal buds available. This selection would have the effect of slowing the development of otherwise dominant trees in an even-aged plantation (Sower and Mitchell, 1987).

Population Monitoring

There are several ways of surveying or monitoring populations of western pine shoot borers in natural and artificially regenerated plantations, seed orchards, and evaluation plantations. Sower et al (1984) evaluated three methods: visual assessment, shoot dissection, and trapping of adult males. Some methods are more labor-intensive than others, and provide greater precision in assessing individual populations. Thus, the purpose of the survey has bearing on the appropriateness of the method used.

A visual survey of trees in a plantation or seed orchard is the quickest and easiest method of assessing shoot borer populations or shoot borer-caused injuries to terminal or lateral shoots, providing the observer is trained to recognize infested shoots. Visual assessment procedures are discussed in the next section. Visual assessment requires no special equipment or supplies, and can be conducted at almost any time of the year. The relatively small size of seed orchards and small plantations lend themselves to use of visual assessment methods to determine shoot borer infestation or shoot borer-caused injury rates.

To provide preliminary estimates of populations, or for generalized surveys of larger areas, Sower et al (1984) found deployment of pheromone-baited traps to be most useful. Trapping surveys, however, require two visits to the site; once to place traps, and once to retrieve traps and count moths captured in traps. An advantage of conducting trapping surveys is that it is not necessary to be skilled in recognizing infested shoots; whereas, trained observers must be used to conduct visual surveys. However, visual surveys by trained observers are probably more appropriate, and more accurate than trapping on specific plantations, where costly management decisions need to be based on the most reliable data that can be obtained within a reasonable amount of time.

The following sections discuss the specific methods of monitoring shoot borer population levels or shoot borer-caused damage. Shoot dissection will not be discussed because it is unlikely that destructive sampling would be conducted for any reason other than to verify the insect's presence, or to demonstrate the larval

feeding habit. Additional details of all survey methods are given in Sower et al (1984).

Population Assessment by External Symptoms

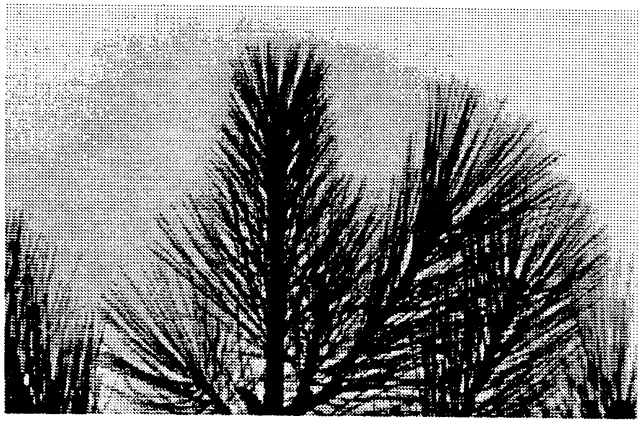
Counting pine shoot borer-infested shoots to determine infestation rates by visual examination of in-place pine terminal shoots is a quick and direct means of population or damage survey for shoot borer in ponderosa pine. The external symptom of infestation is the presence of short needles (relative to other needle lengths on the same tree) beginning at some point on the shoot and extending uniformly to the tip (figure 1.). Sometimes larvae enter the shoot almost from the bud stage and then short needles are present over the entire shoot and the severly shortened shoot has a clubed appearance. The presence of short needles will be accompanied by a general shortening of the shoot's stem, but this will not always be apparent. Terminal shoots equal in length, or shorter than, the longest lateral shoots in the top whorl also indicate pine shoot borer in the terminal. Visual assessments are best made after August, when needles relax into an easily seen horizontal position, and before April, when shoots start to grow again. By late summer, some terminals will be dead and showing yellow coloration.

Various sampling schemes can be used with this method of survey. In plantations, a good method is to walk down rows scoring trees at a pre-determined interval. A total of 50-100 representative terminals need to be examined to get an infestation rate for a stand.

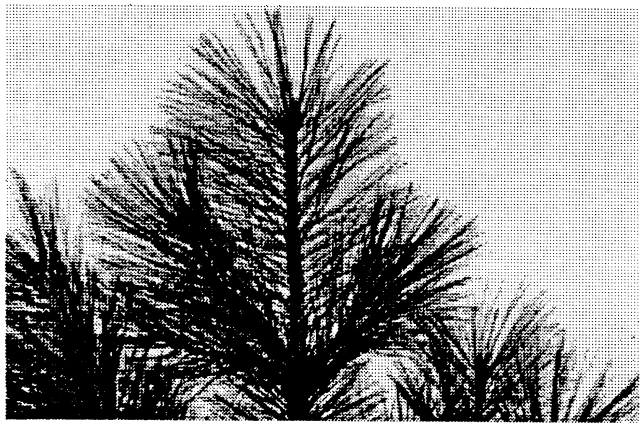
An experienced observer making a visual survey will score about 20% of infested shoots as uninfested. This systematic error is not too important because the missed infestations are mostly those from larvae that enter late, or die early, and thus do little damage to the shoot. The existence of shoots that are hard to score requires that observers have some experience before surveying. The way to gain experience is to practice scoring shoots in a stand where terminals can be examined from close range or dissected to confirm the assessment.

Additional symptoms of shoot borer infestation include the presence of larval mines within the shoot and a 2-3 mm exit hole somewhere towards the middle of the shoot. Exit holes will often be fringed with a bit of browned tissue and may leak pitch. In some stands wind can break off shoots weakened at the exit holes. By the next year, surviving shoots will develop a noticeable swelling in the area of an exit hole. By fall, some infested shoots will have died and faded to yellow.

In lodgepole pine, the same patterns of shoot borer infestation or damage occur, but the symptom of needle shortening is less obvious. Other symptoms of infestation and degree of damage are about the same as for ponderosa pine. In lodgepole pine, shoot borer damage can be confused with similar damage done by the lodgepole terminal weevil, *Pissodes terminalis* Hopping (Sower and Mitchell 1988). Both species cause shoot mortality, particularly in terminals, and the subsequently faded shoots look the same without close examination. The presence of multiple entry and exit holes, particularly towards the tip, indicate infestation and damage due to the weevil; whereas, shoot borer usually bores a single exit hole lower on the stem. Weevils in significant numbers are present intermittently over a stand's rotation; whereas, shoot borer populations are chronic.



a. Infested terminal shoot.



b. Uninfested terminal shoot.

Figure 1. Western pine shoot borer infested (a) and uninfested (b) ponderosa pine terminal shoots.

Trapping Procedures

Capturing and counting moths in pheromone-baited traps is a relatively easy way to monitor shoot borer activity and develop trend data for larger areas. It can also be done on smaller areas such as seed orchards with relatively low cost and a small amount of effort.

For a seed orchard or plantation that ranges in size from roughly 25 to 50 acres, 7-10 traps are an adequate number to provide information on the presence or absence of shoot borers in the stand, or in making preliminary population counts. This procedure is recommended especially when the surveyor is not an "expert" in visually identifying pine shoot borer infested tips.

Traps should be placed randomly throughout representative sites of the orchard or plantation, plus the first 100 yards of susceptible hosts (ponderosa pines and lodgepole pines that are 3-40 ft. tall) beyond the plantation or seed orchard. They should be placed on host species, somewhere in the middle 50 percent of the crown, or at about head height for the larger trees.

The timing of the trapping can be determined by either summation of degree days (DD) or by plant phenology. Adult flight begins at about 50 DD above the development threshold of 5.5 °C after March 1. This roughly coincides with about the time the last patches of winter snow are disappearing, as Manzanita starts to bloom, and as rabbit brush and currents start to flush green. The optimum timing would be the day the first adults fly; but, practically, the timing should be targeted for about a week earlier. The flight season for western pine shoot borer runs from roughly April 1 to the first week in June when the traps can be retrieved and read.

By using a regression equation, the percent of infested tips can be predicted from pheromone trap data. The following equation can be used for this purpose:

$$\hat{Y}=19+0.4X$$

The value X represents the average number of moths captured per trap. $\hat{Y}$ is the predicted value for the percentage of terminals judged infested by observation (i.e. the regression equation was developed by regressing the observed percent of infested leaders on the number of moths captured from the same plots).

Two qualifiers must be stated in regard to this equation: The equation is valid only for traps employing western pine shoot borer synthetic baits of 0.005% by weight, formulated in a poly vinyl chloride matrix contained in 3 mm ID x 10 mm long sections of teflon tubing (Sower et al 1984). A naked 3 mm x 5 mm PVC pellet with 0.01% attractant will give the same result, but will lose attractancy sooner. Any different formulation will give different results; thus, it is important to make sure the baits are properly formulated, or that a calibration of any different bait be made. When purchasing baits from commercial suppliers they will probably need to be custom formulated. "Off-the-shelf" baits will likely contain a different concentration of pheromone, and a different releaser polymer than used by Sower et al (1984)--the study through which the regression equation given above was developed.

The baits used in the study were formulated at the PNW Research Station's Forestry Sciences Laboratory at Corvallis and small quantities might be obtained from that source (L. Sower). Alternatively, they might "calibrate" commercially available baits, to determine equivalent release rates to the baits used in Sower et al's (1984) study.

The second qualifier is that the regression equation is valid only for trapping in ponderosa pine plantations. Since the dependent or response variable in the equation was based on observed infested ponderosa pine leaders, the equation may not by applicable for lodgepole pine plantations. Identifying infested lodgepole pine leaders is much more difficult--even for an expert observer--than for ponderosa pine. Hence, the error associated with observations on lodgepole pine will be different than on ponderosa pine.

Interpretation of Monitoring Results

Once monitoring has been completed, and the percent of infested ponderosa pine terminals has been determined either by direct counts, or calculated with the regression equation, the next course of action, if any, will depend on the relative degree of impact of shoot borer infestation on the resource or management objective(s) for the site. A few examples may help to illustrate: If, for example, an objective for a plantation is to assess family tolerance to shoot borer infestation, relatively high population levels may, in fact, be desirable. In another case, if current need for seed is low, or if the management direction for the plantation is for non-timber resources that are largely unaffected by tree form or seed production, high levels of shoot borer may not be important. In these cases, the site may be able to tolerate a fairly high infestation level without intolerable "damage."

But, what if that is not the case for the site. If shoot borer infestation levels or "damage" are unacceptable for a particular seed orchard or plantation, what do monitoring results mean in terms of need for treatment of the populations to reduce infestation levels or shoot borer-caused damage?

The first task is to establish some relative western pine shoot borer population levels so that monitoring results can be classified and trends conveniently compared. For this purpose, we suggest the following arbitrary infestation categories for ponderosa pine (see table 1.), based on either the survey of visibly-infested shoots or calculated by regression from the trap monitoring results. We have chosen these rates by our personal experience and by noting the relative degree of "acceptability" of rates of shoot borer infestations by seed orchard managers and tree improvement foresters.

Table 1. Qualitative classification of western pine shoot borer populations in ponderosa pine based on percent of infested shoots predicted by regression equation, or enumerated in visual surveys.

Percent Infested Shoots	Population Classification
< 25	Light
26-49	Moderate
> 50	Heavy

Obviously, the degree of "tolerance" of shoot borer infestation or damage is somewhat subjective, and varies from person to person, as well as by resource management objectives as we mentioned above. However, we find the classifications in table 1 to generally reflect the opinions of field personnel involved in tree improvement work, as well as those pest management and research professionals who have experience with western pine shoot borer.

Treatment Thresholds

Since little is known about the natural control of western pine shoot borer (Otvos 1991), and chemical treatments such as use of systemic insecticides have not proven effective (Sartwell et al. 1980), this discussion relating to shoot borer population management is limited to mating disruption techniques with synthetic insect pheromones.

Based on two assumptions, we can state guidelines for a western pine shoot borer treatment threshold. These assumptions apply to the treatment thresholds given in Table 2.: (1) Visibly-infested ponderosa pine terminal shoots result in deformed crowns, and height-growth loss of > 25% per each shoot attacked each year of infestation, when trees are repeatedly attacked (Stoszek 1973; Sower and Shorb 1984); and (2) mating disruption treatments will result in 80% fewer terminals being infested by shoot borers following treatment (Overhulser et al. 1980; Sartwell et al. 1980).

The following table provides guidelines for treatment of western pine shoot borer populations with mating disruption pheromone.

Table 2. Threshold for treatment of western pine shoot borer by mating disruption and estimated levels of protection of ponderosa pine terminal shoots.

Percent Infested Shoots	Protected Terminal Shoots/100 Trees	Comments
25	20	Probably not worth treating.
26-49	20-40	Improvement in vertical growth 0-10% per year.
50	40	Probably improve vertical growth for plantation by about 10% per year. This level of infested terminals is probably about the treatment threshold for a high value stand such as a seed orchard.

As indicated in the table, mating disruption should probably not be considered unless 26% or more of the terminal shoots are infested. Moreover, in terms of benefits derived, the cost of treatment may only be justified--even for high-value seed orchards--when half or more of the terminals are infested.

Protecting the height-growth of trees in a seed orchard until they reach an age in which they begin producing cones may be one strategy to take concerning the need for treatment. It is unclear what effect the killing of terminal shoots by shoot borers ultimately have on seed production; hence, given this uncertainty, it it probably worth providing protection to these trees at least until they reach cone-bearing age, and begin producing seed.

Once more, the above guidelines apply only to ponderosa pine. If the treatment threshold specified above ("Percent Infested Shoots") is higher than desirable for a particular situation, treatment can be initiated at lower levels of infestation or damage, but treatment will result in poorer protection of terminals. In economic terms, this will also result in lower benefit/cost ratios.

Use of Pheromones

Mating Disruption

Typically, mating disruption of western pine shoot borer is accomplished by application of synthetic pheromone-impregnated releasers on, or over, the seed orchard or plantation. Hand applied pheromone strips (lure-tapes) are attached to branches of host trees at the treatment site, or various types of pheromone-formulated plastic polymers are aerially distributed over the proposed treatment area by helicoptor. There are both advantages and disadvantages of both application methods, among which cost (application and material), and availability of sufficient quantities of correctly formulated mating disruption product, are major considerations.

The releasors are typically 0.64 x 41 cm strips of Hercon lure-tape (Hercon Environmental, Emigsville, PA) carrying 5% pheromone by weight. Treatment with 100-200 of these strips per ha results in a dose of 12.5-25 g/ha (5-10 g/acre). The optimum pheromone blend for disruption, or attraction, is about a 4:1 blend of Z-9-dodecenyl acetate to E-9-dodecenyl acetate.

Efficacy for disruption has generally been good except where a small treated stand is closely surrounded by untreated shoot borer habitat, a situation described by Livingston et al. (1984).

Within the industry producing pheromone products for management of populations of economically important insects, there appears to be only low to moderate interest in maintaining fresh stocks of pheromone products for application against western pine shoot borers. This has to do with a number of factors; primarily: (1) present low demand for these products; and (2) lack of federal registration by U.S. Environmental Protection Agency (EPA).

Registration requirements are different depending on whether pheromones are used for mating disruption or for trapping, trap-cropping, or trap-out. Differing registration requirements for mating disruption and "trap" applications appear to be based on legal interpretations and definitions that are beyond the scope of this discussion. Suffice it to say, application of pheromone baits within a trap do not require registration. However, western pine shoot borer mating disruption using either aircraft-applied pheromone in hollow fiber releasers, or hand applied lure-tape baits are currently subject to EPA registration, but neither formulation is currently registered. The lure-tape is still available as an attractant, but the manufacturer makes no claim as to disruption efficacy.

The Forest Service advisory groups, and Forest Pest Management, are aware of the problem with registration of "Minor Use" pest mitigants and may seek solutions in the future. Such relief could come either from a subsidized registration or from a relaxation of EPA requirements for categories of safe materials such as lepidopteran pheromones. In a move towards this latter end, EPA recently announced that it is expanding the acreage cut-off for use of certain classes of pheromones under experimental conditions as authorized by the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), above which the required Experimental Use Permit must be approved by EPA. The experimental application of arthropod pheromones in solid matrix dispensers, used at rates at or below a total use rate of 150 grams active ingredient (AI)/acre/year, in which an EUP is not required has now been increased from 10 to 250 acres. Tests conducted on acreages exceeding 250 acres would require an EUP. Forest Service Manual

2152.3 provides direction for experimental use permits for pesticide research and development projects. Complete regulations are contained in 40 CFR part 172. Additional requirements of this new policy change are available from either of the authors.

Trap-Out

Some seed orchard managers have inquired whether trap-out might be an alternative method to mating disruption for reducing damaging populations of western pine shoot borer owing to the lack of availability of pheromone products for mating disruption, and high cost for custom formulation of mating disruptants.

Since pheromone-baited traps have been exempted from registration by EPA, this strategy may be a reasonable alternative to mating disruption. The efficacy question of this strategy, however, is still an unknown because there are no available research data to provide guidance in this type of application. However, if trap baits are relatively strong, and males attracted to them are frequently captured, then the trap-out strategy may well control pine shoot borers.

This innovation to managing shoot borer populations by trap-out does have possibilities; but, we recommend this approach be undertaken as an "Adaptive Management" project to enable statistically sound experimental designs, and adequate monitoring to identify need for "adjustments" in process or procedures. We encourage consideration of Adaptive Management projects where National Forest System and Forest Service Research can collaborate to address problems of mutual concern, and expand the options available for managing western pine shoot borer populations and damage.

If an Adaptive Management project is undertaken to evaluate the potential for managing shoot borer populations by the trap-out strategy, we suggest that the following methodology be adhered to in the project design.

1. Sticky traps (Delta II or equivalent) should be placed on the orchard or plantation in a grid arrangement with one trap placed every 10 m.

2. Trap baits should be equivalent to the 5% AI Hercon Lure-tape used for disruption, but smaller lengths would be used to reduce the overall dose. Such baits would contain between 10-30 mg of a 4:1 mix of Z-9-dodecenyl acetate and the E-9 isomer per trap rather than the 100 mg per station used for mating disruption. Cost of traps would be offset by reduced cost of attractant as the bait would be about a 5 cm strip of lure-tape rather than a 41 cm strip.

3. Any treatment, trap-out or disruption, should extend beyond the seed orchard or plantation in all host-type stands (ponderosa pine and lodgepole pine) for a distance of at least 100 yards to slow reinvasion of the treated area. Western pine shoot borer moths can fly this distance, so treatment extending at least this distance beyond the orchard or plantation will help to provide a buffer against rapid reinvasion of moths.

4. In every use of shoot borer pheromone, whether for monitoring, mating disruption, or trap-out, it is essential to work with the commercial supplier of the pheromone releasers and monitoring baits to assure that they are properly formulated for the intended application.

Acknowledgements

We thank Bill Gamble, Bear Valley Ranger District, Malheur National Forest, and Mike Straw, Wallowa Valley Ranger District, Wallowa-Whitman National Forest, for their keen interest in managing western pine shoot borer populations on seed orchards they manage. Various discussions with them provided the impetus to bring together pertainent information in one place, both published and unpublished, on monitoring and managing populations of shoot borer in plantations, seed orchards, and other seed production areas. We also gratefully acknowledge Roger Sandquist, Forest Pest Management, Pacific Northwest Region, for providing a review of an earlier draft. His comments and suggestions improved the final document.

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United States Department of Agriculture | Forest Service | PNW, La Grande

Reply to: 3400/1630 **Date:** April 14, 1994

Subject: Western Pine Shoot Borer Guidelines

To: Roger Sandquist

We have recently prepared a report entitled, "Western Pine Shoot Borer Monitoring and Population Reduction Guidelines," Report BMZ-94-09. A copy is enclosed for your use.

The document was developed in response to increasing interest in monitoring and managing western pine shoot borer populations in ponderosa pine seed orchards and young plantations in the Blue Mountains and elsewhere. It brings together current information, both published and unpublished, on recognition of shoot borer infestation, monitoring and evaluating populations, and management by use of pheromones.

Please contact either of the authors if you have questions or desire additional information (Don Scott, 503-962-6545 or DG D.Scott:S26L06A; Lonne Sower 503-750-7377 or DG L.Sower:S26L05A).

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Enclosure

CC: Lonne Sower, PNW, FSL-Corvallis
Craig Schmitt